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Dredging Research
Technical Notes

Engineering Design Considerations for Nearshore Berms

Purpose

Previous investigations of nearshore berms constructed with dredged material have focused on specific pilot projects with only limited effort to provide an experience base evaluation for more generally applicable design recommendations. This Technical Note draws on several completed projects and offers a comprehensive planning level document for nearshore berm design and construction considerations.

Background

An alternative to conventional open-water placement practices, potentially providing beneficial uses of dredged material, is nearshore berm construction. By accurate, controlled placement of dredged material, nearshore berms can be constructed to provide physical and biological benefits. Potential benefits include attenuation of wave energy, introduction of sediment into the littoral system, creation of fish habitat and cost reduction. Zwamborn, Fromme, and Fitzpatrick (1970) and others have demonstrated the physical benefits of submerged mounds, which include wave attenuation and beach profile enhancement. Murden (1988), Clarke, Fredette, and Imsand (1988), and others have documented benefits and potential benefits of underwater berms formed of dredged material, ranging from increased fisheries population and diversity to creating a substrate for oyster colonization, and provided important design factors.

To ensure berm effectiveness, construction cannot be treated as a modification of conventional open-water disposal operations. The berm must be considered an engineered structure, requiring a design template that can be verified, construction methodology, and periodic maintenance throughout the design life of the structure. Traditional equipment and procedures are not precluded from use in nearshore berm

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construction and in fact have been used successfully in several previous projects (McLellan, Truitt, and Flax 1988; and McLellan and Imsand 1989).

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Berm Concept

Conventional open-water placement techniques differ significantly from berm construction operations. In the first case, the dredge contractor is provided with a designated open-water area where material is to be placed. How the material is spread over that area, however, is usually left to his discretion. During berm construction, specific coordinates are defined to receive a specified volume of dredged material with the intent to construct a well defined submerged feature above the normal bottom. The deliberate construction of submerged mounds in relatively deep water, below the influence of wave action, is normally associated with the mitigation of contaminated material (i.e. capping). Construction of a well defined mound reduces surface area which allows economic capping with clean material (Truitt, Clausner, and McLellan 1989). In relatively shallow water, the project designer expects strategically placed mounded material to enhance the local area by interacting with and altering erosive hydrodynamic conditions, thus reducing energy expended upon the coastline, or adding suitable material to the existing profile and allowing natural recovery processes to transport the material in the littoral zone. Shallow and deep-water depths will vary according to local hydrodynamic regimes and be calculated for each project.

If the berm's primary design purpose is energy attenuation, this can be accomplished by placing material with high enough relief and at the proper depth to shoal and break waves, dissipating energy through friction and turbulent diffusion. Since the sediment is not intended to nourish the beach, the construction material is open to a wide range of grain sizes. With proper design and construction, the berm will trip high-energy storms waves, while allowing lower energy beach building waves to progress onto the beach. The berm's stability will be a function of sediment grain size, water content, wave climate, structure dimensions, and side slope steepness. Potential benefits derived from this type of placement include shoreline protection by wave attenuation, reusable sediment stockpile, reduction of costs by reducing haul distances, retention structure for fluid muds, and fisheries habitat.

Beach quality material placed within the littoral system can benefit the shoreline by providing additional sediment to the beach profile. The "feeder" berm material

has the potential for mitigating erosion problems by providing a sacrificial source of sediment; a sill to reduce the movement of material offshore; a source of sand for downdrift areas; and, during times of accretion, a sand source for the beach profile. Feeder berm erosion rates will depend on wave climate, sediment grain size, depth of placement, and berm dimensions. By monitoring and calculating the erosion rates (Anders and Clausner 1989), the berm can be nourished at appropriate intervals to provide a continuing source of sand. In the case of artificial beach nourishment, Bruun (1988) has described how placement of material of suitable grain size material at the proper depth would increase stability and reduce costs when compared to similar material placed on the beach. Whatever the desired objectives, the proper equipment, location, and placement techniques must be selected.

Nearshore Berm Construction

Early nearshore berm construction attempts were limited by the available dredging technology which required water depths of over 11 m for safe dredge maneuvering. Early mounds (see Table 1) remained fairly stable and had little or no measured impact on the beach (Hall 1950). With the advent of shallow-draft, split-hull hopper dredges in the mid- to late 1970's, using conventional dredging and placement practices to construct berms became a reality. The relatively shallow draft, 6.7 m or less, and rapid split-hull placement technique allows the dredge to place material accurately and safely in the active littoral system. *World Dredging, Mining & Construction* (1989) currently lists 13 shallow-draft, split-hull hopper dredges (see Table 2) operating in the United States. The dredges are equipped with modern electronic positioning, which can be used to ensure accurate placement for construction of a well defined submerged feature. Also a growing number of split-hull hopper barges are becoming available for dredging and placement projects.

In 1976 the Corps' Wilmington District placed 26,750 cu m of sand downdrift of the New River Inlet, NC, with the shallow-draft vessel *Currituck*. Schwartz and Musialowski (1977) reported that during the monitoring period the berm migrated landward up to 1.8 m/day, extended the breaker zone offshore, and accreted material on the beach. Within 34 days after disposal, 75 percent of the placed volume had been removed from the construction site. Both the Corps' Mobile and New York Districts have recently constructed nearshore "feeder" berms of dredged material (McLellan, Truitt, and Flax 1988, Bradley and Hands 1989) (Table 1). No significant problems were reported at any of these construction locations as a result of the placement technique.

At the New York District's Fire Island Inlet and Jones Inlet locations, during-construction surveys were used to identify gaps occurring in the berm. The gaps were returned to and filled during the construction process. Additional construction control was provided by plotting the placement locations on a track plotter. The track plot allowed the dredge operator to accurately position the vessel during material placement and to sequence placement events to construct a continuous feature. A second benefit was a margin of safety so the operator could avoid areas that had become too shallow for safe navigation. Depth and sea-state safety constraints

Table 1

Nearshore Berms Constructed With Dredged Material

Location	Date	Material Quantity cu m	Material Type	Water Depth m	Mound Height m	Reference
Santa Barbara, CA	1935	153,000	sand	6.1	NA	Hall (1950)
Atlantic City, NJ	1935-1942	2.7 million	sand	4.6-7.6	NA	Hall (1950)
Long Branch, NJ	1948	460,000	sand	11.6	2.1	Hall (1950)
Durban, South Africa	1970	8.0 million	sand	15.0	7.7	Zwamborn, Fromme, & Fitzpatrick (1970)
New River Inlet, NC	1976	26,750	sand	1.8-4.0	NA	Schwartz & Musialowski (1977)
Dam Neck, VA	1982	650,000	silty sand	11.0	3.3	Hands & DeLoach (1984)
Sand Island, AL	1987	300,000	sand	5.7	2.1	Bradley & Hands (1989)
Fire Island, NY	1987	320,000	sand	4.9	2.0	McLellan, Truitt, & Flax (1988)
Jones Inlet, NY	1987	300,000	sand	4.9	2.0	McLellan, Truitt, & Flax (1988)
Mobile North, AL	1988-1989	14.3 million	clay, silt, & sand	10.7-13.7	6.6	McLellan & Imsand (1989)

Table 2

United States Split-Hull Hopper Dredges

With Less Than 6.7-m Draft

Dredge	Owner	Year Built	Loaded Draft m	Maximum Capacity cu m	Dredging Depth m	Length m
Currituck	Corps of Engineers	1973	2.1	239	6.1	43.9
Newport	Manson Const. Co.	1976	5.5	3,057	19.8	80.8
Westport	Manson Const. Co.	1976	3.7	1,376	19.8	54.9
Manhattan Island	North American Trailing Co (NATCO)	1977	5.8	2,751	21.3	85.6
Sugar Island	NATCO	1979	5.8	2,751	21.3	85.6
Atchafalaya	Gulf Coast Trailing Co.	1980	4.6	993	19.8	60.0
Dodge Island	NATCO	1980	5.8	2,751	21.3	85.6
Mermentau	Gulf Coast Trailing Co.	1981	4.6	993	19.8	60.0
Padre Island	NATCO	1981	5.8	2,828	21.3	85.6
Eagle I	Bean Dredging Co.	1981	6.7	4,215	24.4	103.6
Northely Island	NATCO	1983	4.6	1,651	13.7	62.5
Ouachita	Gulf Coast Trailing Co.	1985	6.7	2,943	19.8	90.5
Atlantic American	American Dredging Co.	1987	5.8	3,042	21.3	89.6

should be discussed with the dredge contractor prior to construction. Alternatives, such as slightly deeper placement or an alternative site, should be available during times of high sea state.

Zwamborn, Fromme, and Fitzpatrick (1970) describe a berm designed as a wave filter to reduce erosive energy upon the beaches of Durban, South Africa. Scale and prototype tests demonstrated reduction of beach erosion and wave energy. Physical model test results showed a reduction in nonbreaking wave height of 30 percent, while the amount of reduction increased rapidly with breaking waves. During one major Durban storm, protection of the beaches was demonstrated with little loss of elevation to the berm.

During the early 1980's, the Corps constructed a stable berm at the Dam Neck site off the coast of Virginia (Hands and DeLoach 1984). The berm demonstrated the ability and stability of constructing a definable offshore berm with relatively fine-grained dredged material using split-hull hopper dredges. McLellan and Imsand (1989) describe a stable berm currently being constructed by the Mobile District in the Gulf of Mexico, using 14.3 million cu m of sand to clay-sized dredged material. With such large volumes, navigational accuracy used for the berm construction is not as critical as with the feeder berms; however, placement control and construction monitoring are required to ensure that the design of the structure is completed properly.

Nearshore Berm Design

Zwamborn, Fromme, and Fitzpatrick (1970), Frisch (1979), and Gunyakti (1987) have stressed the importance of design in the berm construction process. Factors such as sediment type, construction methodology, local wave and hydrological climate, depth, berm height, and orientation must all be taken into account to ensure the berm performs as the designers intended. Improper planning and design can lead to problems, as discussed by Ludwick and Saumsiegle (1976). Numerical model studies of an offshore disposal site showed that improperly mounded dredged material can cause convergence of wave rays in the lee of the berm, increasing wave height by as much as 20 percent. In addition Zwamborn, Fromme, and Fitzpatrick (1970) discussed shoreline erosion caused by the focusing of wave energy from berm edge effects during Durban Beach stable berm construction. Berm construction is not without its problems, but with proper design, stringent placement controls, coupled with a well-planned preconstruction, construction, and postconstruction monitoring, most of the potential problems can be avoided.

To prevent wave focusing and better produce attenuating effects, Zwamborn, Fromme, and Fitzpatrick (1970), Frisch (1979), and Gunyakti (1987) suggest the construction of a linear feature and avoidance of singular conical shapes. Orientation of the berm will be determined by intent and local restrictions, but in most cases will be shore-parallel to take advantage of energy-reduction benefits. In deeper water berms, wave-focusing edge effects can be reduced by placing material along the entire length of the structure to raise the bottom elevation to the desired depth in

increments. This technique reduces the chance of creating a wave-focusing conical shape during the construction process. As mentioned, periodic bathymetric surveys can be used during construction to identify gaps in the structure that can be filled.

Material must be placed within the active littoral zone if it is to provide beach enhancement. Hallermeier (1981), Birkemeier (1985), and others have discussed methods for calculating the seaward limit of sediment transport. Within the active limit, increasing depths diminish the percentage of placed material moving in to enhance the beach profile and increase the time required for the material to move. The optimum construction depth varies with sediment type, and wave period, height, and steepness. For the Dutch coastline, Roeluink (1989) used a two-dimensional model to indicate little beach enhancement benefits were derived by placing material deeper than the 8-m contour. Local studies can also be conducted to determine the most advantageous location. McLellan and Burke (1988) used seabed drifters (a bottom trailing drogue), current measurements, wave hindcast data, and sand samples to delineate the best berm construction site downdrift of the Brazos-Santiago Pass Jetties offshore of South Padre Island, TX.

Local hydrodynamic conditions play a major role in the rate, amount, and direction of movement of material from a nearshore berm. Although accurate prediction of storm or wave climate is difficult, wave hindcast data or numerical models are usually available to determine seasonal trends in wave energy and littoral drift direction as well as conditions for specific storm events. Using hindcast data will not only aid in selection of proper location but also the appropriate time for placement. Wave Information Studies data (McAneny 1986), a 20-yr compilation of hindcast data, was used to help determine the most advantageous time and location to construct a berm off South Padre Island (McLellan and Burke 1988). The hindcast data indicated a southern littoral drift in the fall and early winter months and a northerly drift the remaining months of the year. Since the berm was constructed north of the channel, the best time for construction was during the late winter through spring to ensure material moved north and not back into the channel.

Design and construction of nearshore stable features with dredged material have been described by Hall (1950), Zwamborn, Fromme, and Fitzpatrick (1970), and McLellan and Imsand (1989). To serve as protection for beaches, the mounded material must rise above the seafloor to an elevation that will selectively filter the waves as they approach. By allowing low-energy waves to pass unhindered while breaking the large erosive waves, the feature can provide beach protection. The berm must also be sufficiently stable if it is to perform its function for a significant period of time. Zwamborn, Fromme, and Fitzpatrick (1970) used nearshore bar technology developed by Keulegan (1945) to determine that the depth of the berm crest should be about half the water depth to remain stable. Increasing crest widths were also shown to improve wave-breaking ability and reduce wave heights in the lee of the berm. Stability and wave-filtering capability will ultimately be a function of depth of placement, crest elevation, grain size, placement method and deep-water wave height, period, and steepness.

Summary and Conclusions

A properly designed berm can provide benefits by reducing erosive wave energy on the shoreline or introducing beach quality sediment into the profile. Modeling and analysis techniques are available to aid in selecting the best location and orientation for berm construction. Feeder berms placed to enhance the beach should be limited to beach quality sands and placed at a suitable depth. The shallower the placement, the quicker and greater volume of placement sediment moves into the littoral system. Stable berms designed for wave filtering are open to a wide sediment range.

With the advent of well equipped, shallow-draft, split-hull hopper dredges and barges, the capability to construct a well defined submerged feature using dredged material is greatly increased. By using a track plotter, better safety and placement accuracy can be achieved. During construction, monitoring should be conducted to ensure that a well defined linear feature is developed. High-relief conical features have the potential of focusing, rather than attenuating wave energy, and should be avoided in the nearshore zone.

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